
47
FUNCTIONAL ERROR HANDLING
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Functional Error Handling

Requirements

1. Arm a Nuke launcher
2. Aim toward a Target
3. Launch a Nuke and impact the Target

Requirements

1. **arm** a **Nuke** launcher
2. **aim** toward a **Target**
3. **launch** a **Nuke** and **Impact** the **target**

Requirements

```scala
/** model */
case class Nuke()
case class Target()
case class Impacted()

def arm: Nuke = ???
def aim: Target = ???
def launch(target: Target, nuke: Nuke): Impacted = ???
```

Exceptions

```
def arm: Nuke = throw new RuntimeException("SystemOffline")
def aim: Target = throw new RuntimeException("RotationNeedsOil")
def launch(target: Target, nuke: Nuke): Impacted = Impacted()
```

Exceptions

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def arm: Nuke = throw new RuntimeException("SystemOffline")
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def launch(target: Target, nuke: Nuke): Impacted = Impacted()
```

Breaks Referential transparency

Exceptions: Broken GOTO

```
def arm: Nuke = throw new RuntimeException("SystemOffline")
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def launch(target: Target, nuke: Nuke): Impacted = Impacted()
```

They are a broken GOTO

Exceptions: Broken GOTO

```
def arm: Nuke = throw new RuntimeException("SystemOffline")
def aim: Target = throw new RuntimeException("RotationNeedsOil")
def launch(target: Target, nuke: Nuke): Impacted = Impacted()

def attack: Future[Impacted] = Future(launch(arm, aim))
```

They are a broken GOTO... getting lost in async boundaries

Exceptions

```
at java.lang.Throwable.fillInStackTrace(Throwable.java:-1)
at java.lang.Throwable.fillInStackTrace(Throwable.java:782)
- locked <0x6c> (a sun.misc.CEStreamExhausted)
at java.lang.Throwable.<init>(Throwable.java:250)
at java.lang.Exception.<init>(Exception.java:54)
at java.io.IOException.<init>(IOException.java:47)
at sun.misc.CEStreamExhausted.<init>(CEStreamExhausted.java:30)
at sun.misc.BASE64Decoder.decodeAtom(BASE64Decoder.java:117)
at sun.misc.CharacterDecoder.decodeBuffer(CharacterDecoder.java:163)
at sun.misc.CharacterDecoder.decodeBuffer(CharacterDecoder.java:194)
```

Abused to signal events in core libraries

Exceptions

```
try {
  doExceptionalStuff() //throws IllegalArgumentException
} catch (Throwable e) { //too broad matches:
    /*
    VirtualMachineError
    OutOfMemoryError
    ThreadDeath
    LinkageError
    InterruptedException
    ControlThrowable
    NotImplementedError
    */
}
```

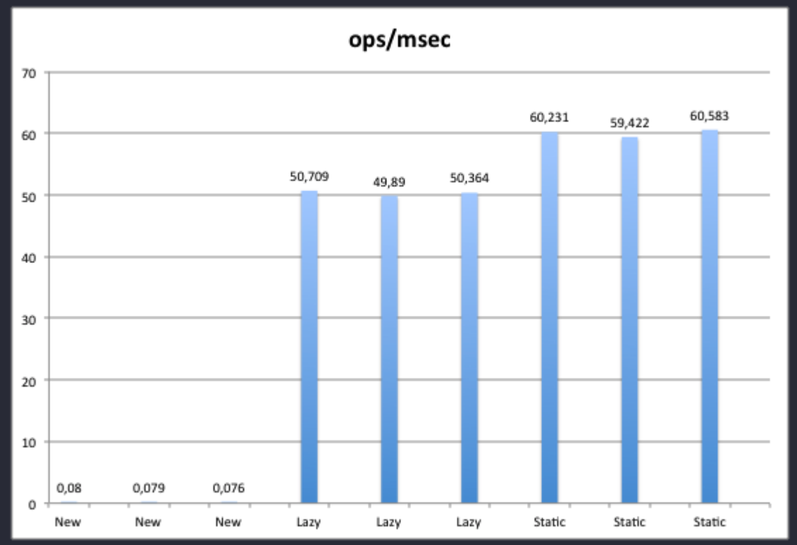
Unsealed hierarchies, root of all evil

Exceptions

```
public class Throwable {
    /**
     * Fills in the execution stack trace.
     * This method records within this Throwable object information
     * about the current state of the stack frames for the current thread.
     */
    Throwable fillInStackTrace()
}
```

Potentially costly to construct based on VM impl and your current Thread stack size

Exceptions



The Hidden Performance costs of instantiating Throwables

- *New: Creating a new Throwable each time*
- *Lazy: Reusing a created Throwable in the method invocation.*
- *Static: Reusing a static Throwable with an empty stacktrace.*

Exceptions

Poor choices when using exceptions

- Modeling absence
- Modeling known business cases that result in alternate paths
- Async boundaries over unprincipled APIs (callbacks)
- When people have no access to your source code

Exceptions

Maybe OK if...

- You don't expect someone to recover from it
- You are contributor to a JVM in JVM internals
- You want to create caos and mayhem to overthrow the government
- In this talk
- You know what you are doing

How do we model exceptional cases then?

MONADS!

Option

When modeling the potential absence of a value

Option

When modeling the potential absence of a value

```scala
sealed trait Option[+A]
case class Some[+A](value: A) extends Option[A]
case object None extends Option[Nothing]
```

Option

Useful combinators

```
def fold[B](ifEmpty: ⇒ B)(f: (A) ⇒ B): B //inspect all paths
def map[B](f: (A) ⇒ B): Option[B] //transform contents
def flatMap[B](f: (A) ⇒ Option[B]): Option[B] //monadic bind to another option
def filter(p: (A) ⇒ Boolean): Option[A] //filter with predicate
def getOrElse[B >: A](default: ⇒ B): B //extract or provide alternative
```

Garbage

```
def get: A //NoSuchElementException if empty (╯°□°)╯ ︵ ┻━┻
```

Option

How would our example look like?

```
def arm: Option[Nuke] = None
def aim: Option[Target] = None
def launch(target: Target, nuke: Nuke): Option[Impacted] = Some(Impacted())
```

Option

Pain to deal with if your lang does not have proper Monads or syntax support

```
def attackImperative: Option[Impacted] = {
  var impact: Option[Impacted] = None
  val optionNuke = arm
  if (optionNuke.isDefined) {
    val optionTarget = aim
    if (optionTarget.isDefined) {
      impact = launch(optionTarget.get, optionNuke.get)
    }
  }
  impact
}
```

Option

Easy to work with if your lang supports monad comprehensions or special syntax

```
def attackMonadic: Option[Impacted] =
for {
  nuke <- arm
  target <- aim
  impact <- launch(target, nuke)
} yield impact
```

Try

When a computation may fail with a runtime exception

Try

When a computation may fail with a runtime exception

```scala
sealed trait Try[+T]
case class Failure[+T](exception: Throwable) extends Try[T]
case class Success[+T](value: T) extends Try[T]
```

Try

Useful combinators

```
def fold[U](fa: (Throwable) ⇒ U, fb: (T) ⇒ U): U //inspect all paths
def map[U](f: (T) ⇒ U): Try[U] //transform contents
def flatMap[U](f: (T) ⇒ Try[U]): Try[U] //monadic bind to another Try
def filter(p: (T) ⇒ Boolean): Try[T] //filter with predicate
def getOrElse[U >: T](default: ⇒ U): U // extract the value or provide an alternative if exception
```

Garbage

```
def get: T //throws the captured exception if not a Success (╯°□°)╯ ︵ ┻━┻
```

Try

How would our example look like?

```
def arm: Try[Nuke] =
  Try(throw new RuntimeException("SystemOffline"))

def aim: Try[Target] =
  Try(throw new RuntimeException("RotationNeedsOil"))

def launch(target: Target, nuke: Nuke): Try[Impacted] =
  Try(throw new RuntimeException("MissedByMeters"))
```

Try

Pain to deal with if your lang does not have proper Monads or syntax support

```
def attackImperative: Try[Impacted] = {
  var impact: Try[Impacted] = null
  var ex: Throwable = null
  val tryNuke = arm
  if (tryNuke.isSuccess) {
    val tryTarget = aim
    if (tryTarget.isSuccess) {
      impact = launch(tryTarget.get, tryNuke.get)
    } else {
      ex = tryTarget.failed.get
    }
  } else {
    ex = tryNuke.failed.get
  }
  if (impact != null) impact else Try(throw ex)
}
```

Try

Easy to work with if your lang supports monadic comprehensions

```
def attackMonadic: Try[Impacted] =
for {
  nuke <- arm
  target <- aim
  impact <- launch(target, nuke)
} yield impact
```

Either

When dealing with a known alternate return path

Either

When a computation may fail or dealing with known alternate return path

```scala
sealed abstract class Either[+A, +B]
case class Left[+A, +B](value: A) extends Either[A, B]
case class Right[+A, +B](value: B) extends Either[A, B]
```

Either

Useful combinators

```
def fold[C](fa: (A) ⇒ C, fb: (B) ⇒ C): C //inspect all paths
def map[Y](f: (B) ⇒ Y): Either[A, Y] //transform contents
def flatMap[AA >: A, Y](f: (B) ⇒ Either[AA, Y]): Either[AA, Y] //monadic bind if Right
def filterOrElse[AA >: A](p: (B) ⇒ Boolean, zero: ⇒ AA): Either[AA, B] //filter with predicate
def getOrElse[BB >: B](or: ⇒ BB): BB // extract the value or provide an alternative if a Left
```

Garbage

```
toOption.get, toTry.get //Looses information if not a Right (╯°□°)╯ ︵ ┻━┻
```

Either

What goes on the Left?

```
def arm: Either[?, Nuke] = ???
def aim: Either[?,Target] = ???
def launch(target: Target, nuke: Nuke): Either[?, Impacted] = ???
```

Either

Alegbraic Data Types (sealed families)

```
sealed trait NukeException
case class SystemOffline() extends NukeException
case class RotationNeedsOil() extends NukeException
case class MissedByMeters(meters : Int) extends NukeException
```

Either

Algebraic data types (sealed families)

```
def arm: Either[SystemOffline, Nuke] = Right(Nuke())
def aim: Either[RotationNeedsOil,Target] = Right(Target())
def launch(target: Target, nuke: Nuke): Either[MissedByMeters, Impacted] = Left(MissedByMeters(5))
```

Either

Pain to deal with if your lang does not have proper Monads or syntax support

```
def attackImperative: Either[NukeException, Impacted] = {
  var result: Either[NukeException, Impacted] = null
  val eitherNuke = arm
  if (eitherNuke.isRight) {
    val eitherTarget = aim
    if (eitherTarget.isRight) {
      result = launch(eitherTarget.toOption.get, eitherNuke.toOption.get)
    } else {
      result = Left(RotationNeedsOil())
    }
  } else {
    result = Left(SystemOffline())
  }
  result
}
```

Either

Easy to work with if your lang supports monadic comprehensions

```
def attackMonadic: Either[NukeException, Impacted] =
for {
  nuke <- arm
  target <- aim
  impact <- launch(target, nuke)
} yield impact
```

Either

Easy to work with if your lang supports monadic comprehensions

Can we further generalize error handling and launch nukes on any M[_]?

(Monad|Applicative)Error[M[_], E]

```
/**
 * A monad that also allows you to raise and or handle an error value.
 * This type class allows one to abstract over error-handling monads.
 */
trait MonadError[F[_], E] extends ApplicativeError[F, E] with Monad[F] {
  ...
}
```

(Monad|Applicative)Error[M[_], E]

Many useful methods to deal with potentially failed monads

```
def raiseError[A](e: E): F[A]
def handleError[A](fa: F[A])(f: E => A): F[A]
def attempt[A](fa: F[A]): F[Either[E, A]]
def attemptT[A](fa: F[A]): EitherT[F, E, A]
def recover[A](fa: F[A])(pf: PartialFunction[E, A]): F[A]
def catchNonFatal[A](a: => A)(implicit ev: Throwable <:< E): F[A]
def catchNonFatalEval[A](a: Eval[A])(implicit ev: Throwable <:< E): F[A]
```

(Monad|Applicative)Error[M[_], E]

Cats instances available for

```
MonadError[Option, Unit]
MonadError[Try, Throwable]
MonadError[Either[E, ?], E]
```

(Monad|Applicative)Error[M[_], E]

How can we generalize and implement this to any M[_]?

```scala
def arm: M[Nuke] = ???
def aim: M[Target] = ???
def launch(target: Target, nuke: Nuke): M[Impacted] = ???
```

(Monad|Applicative)Error[M[_], E]

Higher Kinded Types!

```scala
def arm[M[_]]: M[Nuke] = ???
def aim[M[_]]: M[Target] = ???
def launch[M[_]](target: Target, nuke: Nuke): M[Impacted] = ???
```

(Monad|Applicative)Error[M[_], E]

Typeclasses!

```
import cats._
import cats.implicits._

def arm[M[_] : NukeMonadError]: M[Nuke] =
  Nuke().pure[M]

def aim[M[_] : NukeMonadError]: M[Target] =
  Target().pure[M]

def launch[M[_] : NukeMonadError](target: Target, nuke: Nuke): M[Impacted] =
  (MissedByMeters(5000): NukeException).raiseError[M, Impacted]
```

(Monad|Applicative)Error[M[_], E]

An abstract program is born

```
def attack[M[_] : NukeMonadError]: M[Impacted] =
  (aim[M] |@| arm[M]).tupled.flatMap((launch[M] _).tupled)
```

(Monad|Applicative)Error[M[_], E]

Provided there is an instance of MonadError[M[_], A] for other types you abstract away the return type

```
attack[Either[NukeException, ?]]
attack[Future[Either[NukeException, ?]]]
```

Abstraction

- Benefits
  - Safer code
  - Less tests
  - More Constrains
  - More runtime choices
- Issues
  - Performance cost?
  - Newbies & OOP dogmatics complain about legibility
  - Advanced types + inference == higher compile times

Recap

Error Handling	*When to use*	*Java*	*Kotlin*	*Scala*
Exceptions	~Never	x	x	x
Option	Modeling Absence	?	x	x
Try	Capturing Exceptions	?	?	x
Either	Modeling Alternate Paths	?	?	x
MonadError	Abstracting away concerns	-	-	x

Recap

What if my lang does not support some of these things?

1. Build it yourself
2. Ask lang designers to include HKTs, Typeclasses, ADT and others
3. We are part of the future of programming

Thanks!

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